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Other

What common design principles can be distilled out from literature in the field of technologies and learning difficulties that might inform the design of technologies within the EU funded ARCHES Project?

Jane Seale, Helena Garcia-Carrisoza, Jonathan Rix, Kieron Sheehy; Open University, UK
Simon Hayhoe, Bath University, UK

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INTRODUCTION

The focus of this research report is people who have diverse access needs associated with perception, memory, cognition and communication- those who are frequently ascribed the label of 'learning difficulties'[1] and the technologies that may help to enhance their access to and inclusion into cultural and heritage sites (including digital assets).

There is an increasing recognition of the potential value of cultural and heritage sites to people with learning difficulties as spaces to support the pursuit of educational, social and leisure opportunities (Hooper-Greenhill *et al.* 2002). There is also a growing appreciation that people with learning difficulties should be involved in assessing heritage site provision (Rayner 1998; Economou 1999; Ruiz 2004; Rix 2005). For example, Rix and Lowe (2010) describe 'The Access to Heritage Project', which began in autumn 2005 and aimed to assist and encourage people with learning difficulties to access Merseyside's culture and heritage sites; to enable heritage sites to learn from people with learning difficulties about how to best make themselves accessible to people with learning difficulties and therefore benefit everyone and to create intellectual access guidance that can be used in heritage sites everywhere. Rix and Lowe (2010) detail the approach taken by the Heritage Forum which provides a flexible protocol regarding ways of working with groups and individuals with learning difficulties.

Initiatives like 'The Access to Heritage Project' are not common, and therefore despite increasing recognition of the potential value of cultural and heritage sites to people with learning difficulties, there is still a lack of resources targeted specifically at those who face barriers in relation to structuring thought, remembering and communicating. Heritage sites in many countries now make provision for people with a wide variety of physical and sensory disabilities. Some sites offer audio tours, others have occasional targeted tours or one-off projects while a number have accessible signage, but there is no clear picture of current provision and little analysis of the intellectual accessibility of sites. Rix (2005) argues that whilst a number of organisations offer advice on how best to provide access to sites and their artefacts, and carry out audits of physical and sensory access, there is little to assist with intellectual access.

We have identified two potential approaches to addressing the access and inclusion issues that people with learning difficulties experience in relation to cultural and heritage sites:

1. The development and employment of technologies;
2. The implementation of inclusive or participatory approaches to research and design in the field.

An example of how technologies can be used to facilitate inclusive experiences of heritages sites for people with learning difficulties is the 'Sensory Object Project', described by Hollinworth *et al.* (2012). Hollinworth *et al.* highlight how the handling of artworks can enhance our understanding

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[1] The term 'people with learning difficulties' is one of many used to describe people who are identified as having differences in relation to thinking, remembering and communicating. These individuals are commonly sorted into a whole raft of label subgroups which change across the years [Rix, 2006]. In using the term 'people with learning difficulties' this paper adopts the language advocated by self-advocates such as Simons in [Simons, 1992] and self-advocacy groups such as People First [PeopleFirst] in [PeopleFirst, 1992]. They request that labelled individuals are recognised as people before anything else, and that we use the term 'learning difficulties' to remind others that they can learn for the whole of their lives like everyone else.

of cultural heritage, particularly for those people with learning difficulties. For this social group, hands-on experience of cultural objects has become an important approach in promoting an understanding of cultural heritage. The aim of the 'Sensory Object Project' therefore was to create a series of multisensory, multimedia interactive art works that respond to, and take place of, equivalent objects in museum collections, developed through art-based workshops by people with learning difficulties in collaboration with an interdisciplinary research team. Using participatory methods the project aimed to give people with learning difficulties access to technology, and provide this in such a way that they can appreciate the purpose of the technology and its potential uses in cultural and heritage site contexts.

The 'Sensory Object Project' provides a useful illustration of how inclusive or participatory approaches can involve people with learning difficulties in improving the accessibility or inclusivity of cultural and heritage sites and their digital assets. Inclusive research by people with learning difficulties has developed from an emancipatory research model. Emancipatory disability research focuses upon the need for research to be accountable and open throughout to a group run by disabled people, with the skills and knowledge of researchers being at the disposal of disabled people (Barnes, 2003), aiming to produce accessible knowledge, using methods that are rigorous and place findings within their environmental and cultural context so as to highlight the disabling consequences of society (UKDPC, 2003). Walmsley and Johnson (2003) identify three core principles of inclusive research: "research must address issues which really matter to people with learning difficulties, and which ultimately lead to improved lives for them"; "it must access and represent their views and experience"; and "people with learning difficulties need to be treated with respect by the research community."

Both technologies and inclusive research approaches are being employed in the EU funded ARCHES project. In this research report we will introduce the work of the ARCHES project, an EU funded project that aims, through the development and employment of technologies, to create more inclusive environments for people with learning difficulties (as well as people who experience other difference and difficulties). In particular, this report will present and discuss the results of a comprehensive literature review that is designed to inform the early work of the ARCHES project.

THE ARCHES (ACCESSIBLE RESOURCES FOR CULTURAL HERITAGE ECOSYSTEMS) PROJECT

ARCHES (Accessible Resources for Cultural Heritage EcoSystems) is a Horizon 2020 funded project that involves heritage and technology partners across Europe. The overarching objective of the ARHCES project is to:

> *Create more inclusive cultural environments for people with differences and difficulties associated with perception, memory, cognition and communication*[1] *through an in-depth research analysis and the development of innovative applications, functionalities and experiences based on the reuse and redevelopment of digital resources.*

Related to this global objective is a set of research, development and innovation objectives that include:

- **RO1**: To develop and evaluate strategies which enable an exploration of the value, form and function of mainstream technologies by and for people with differences and difficulties associated with perception, memory, cognition and communication.

- **RO2**: To develop and evaluate the use of mainstream technologies to enable inclusion of people with such disabilities as museums visitors and consumers of art.

Over the period of three years, therefore, the ARCHES project will develop online resources, software applications and multisensory technologies to enable people with differences and difficulties associated with perception, memory, cognition and communication to access Cultural Heritage Sites. Within the project we acknowledge that many disabled people do not associate with the ubiquitously used labels that are typically applied to people that experience such differences and difficulties. Examples of such labels include sensory impairment, visual impairment, hearing impairment, deaf/hard of hearing, blind and learning difficulties. The focus of the project is adults (people over the age of 18) rather than children. Examples of the mainstream technologies that the technical partners of the project are focusing on developing include virtual or augmented reality applications; 3D haptic devices and serious game applications. In order to meet these (and other) objectives, the ARCHES project has three phases:

1. Phase 1 will involve developing new technologies.
2. Phase 2 will involve testing and redeveloping these technologies.
3. Phase 3 will involve checking the new technologies are ready for other people to use.

Each of these phases is underpinned by inclusive research methods; therefore in each participating country, participatory research groups with people with differences and difficulties associated with perception, memory, cognition and communication will be set up. Within these groups, participants will have a role to play in evaluating their experiences of activities and resources within cultural and heritage sites; suggesting ways in which technologies might enhance their experiences or resources; evaluating test or beta-versions of technologies and analysing the processes and outcomes of the project as a whole.

The role of literature reviews in the context of an inclusive research project like ARCHES

As part of the early work of the ARCHES we have concluded that it would be helpful to conduct an in-depth analysis of two particular fields of research and practice literature:

1. The broad literature focusing on the design and development of technologies for people with learning difficulties in any context (i.e. beyond cultural and heritage sites).
2. The broad literature focusing on the use of inclusive (or participatory approaches) to designing technologies for people with learning difficulties in any context (i.e. beyond cultural and heritage sites)

The results of the second literature review will be reported elsewhere. In this research report we will present the results of the first literature review. It is our intention that distilling out common design principles from the literature might inform the work of the technical partners within the

ARCHES project. It is not our intention that the literature review results be prioritised above any design characteristics that the participatory research groups suggest; rather it is our intention that the literature review results will complement the work and suggestions emanating from the participatory research groups. For example, any design principles identified by the literature review may help to put participants' comments and feedback into a context and explain why they might be focusing on particular aspects. Alternatively, implementing some of the design principles suggested by the literature review, prior to showing participants' prototype designs, may help to decrease what might be considered the 'extraneous noise' that can happen in evaluation sessions; where designs are potentially so poor that users have to spend more time commenting on the device or technology and less time commenting on how the device enabled access to the cultural or heritage site. In this report therefore we will report the results of a literature review that aimed to address the question:

> *What common design principles can be distilled out from literature in the field of technologies and learning difficulties that might inform the design of technologies within the EU funded ARCHES Project?*

METHOD

The literature review took place between October and December 2016. The parameters of the review are laid out in Table 1. A range of databases were searched in order to reflect the multidisciplinary nature of research in the field of learning disability and technology design. A particular focus of the search was the design of technologies similar to those being developed within the Arches project. A range of keyword terms were used to search for outputs related to learning disability in order to reflect the national and disciplinary differences in labels used to categorise this group of people. The date range of the search was restricted to the last ten years in anticipation that design principles may be quite different for older out of date technologies designed and evaluated prior to 2006. In each literature database, 24 separate searches were conducted using a two level search strategy:

First level search		**Second level search**
Learning disabilities		Mobile technology
Learning difficulties	AND	Games
Intellectual impairment		Virtual reality
Cognitive impairment		Augmented reality
		Haptic device
		Software

These searches produced 75 papers which were then downloaded and recorded. The first author read all 75 papers and made recommendations regarding whether the paper should be included in the review based on the extent to which it addressed the research question. A co-researcher then read the abstracts of the papers along with the recommendations and mediated the decisions made by the first author. This two-level filtering process reduced the number of papers down to a corpus of 45 (See Appendix 1). When referring to these papers in the proceeding results section we will refer to them by their allocated number, 1 to 45, as listed in Appendix 1.

Date range	2010-2016
Language(s)	English
Literature Databases	CiteSeerX Association for Computing Machinery Digital Library IEEE Explore SCOPUS
Journal databases	SpringerLink Science Direct Journals Elsevier Proquest dissertations
Types of publication	Journal articles and conference papers
Inclusion criteria	Papers must be evaluative as well as descriptive- enabling lessons to be drawn from the results or experiences
	Must involve learning disabilities
	Must involve one of the following technologies: General Software Serious games Virtual reality- avatars Augmented reality Haptic devices Mobile technologies
Keyword terms	Learning disabilities Learning difficulties Intellectual impairment Cognitive impairment Mobile technology Games Virtual reality Augmented reality Haptic device software

Table 1: The parameters of the literature review

RESULTS

In presenting the results of our literature review we will begin by providing an overview of the corpus of papers found in our search in order to provide a detailed context for the review findings; particularly in relation to differences and difficulties, age range, technologies and intended purpose of technology use. Following this overview, we will then focus on using the literature found in our review to answer the following three questions:

1. What common design principles can be distilled from the literature?
2. How were the design principles derived or evidenced within the literature?
3. What factors might influence the application of the identified design principles

Overview of the corpus

There were three different types of paper produced by the literature search. Thirty-one papers which reported the design and evaluation of new technologies. For example, Yao-Jen Chang, et al. (2016) describe how they combined Microsoft Kinect technology and image recognition technology to create a pedestrian safety training system for young people with learning difficulties [6]. Ten papers reported the design specification of a new technology prior to evaluation by intended users [2, 4, 5, 10, 12, 14, 22, 24, 42, 44]. For example, Arteaga *et al.* (2015) put forward a proposal for 'The SMART ANGEL project' aimed to use cloud and mobile technologies to support autonomous movements in town of people with learning difficulties [2]. Four papers reported the results of surveys or observational studies regarding technology use and needs of people with learning disabilities [8, 29, 33, 36]. For example, Feng *at al.* (2010) report the results of a survey of 513 parents in the United States regarding the difficulties that children with Down Syndrome experience when using computers [8].

The 45 papers spanned research from countries in North America (United States); Central America (Mexico); South America (Brazil); Europe (Italy, France, Spain, Germany, Portugal, Finland, Lithuania, Hungary, UK); Asia (Taiwan, Japan, Sri Lanka) and the Middle East (Qatar). Four of the papers report the work of EU funded projects [24, 38, 41, 40]. For example, Kultsova *et al.* (2016) describe a project carried out in an EU project called 'Community Service Engineering' which involved staff, PhD and Masters students at Thomas More University in Belgium and the Software Engineering Department at Volgograd State Technical University in Russia. A mobile application called 'Travel and Communication Assistant' has been developed which supports people with learning difficulties to independently travel a known route (for example a route from home to the day care centre) under the remote supervision of their caregivers and to communicate with them using text, voice and pictogram messages [24].

Differences and difficulties

All the studies included in this review involved at least one participant with a learning disability; for example those labelled as having 'special educational needs' or Down Syndrome'[2]. In addition to this, some studies focussed entirely on Autism or ADHD and given that individuals with this

[2] We recognise that we have made an assumption that the term 'learning disability' would be commonly accepted as an alternative term to 'special educational needs' or 'Down Syndrome'.

diagnosis may not have sensory or intellectual impairments we could not reliably draw upon them. Other excluded studies focused on participants with other non-learning related differences such as motor impairment, dementia or schizophrenia. Six studies included people with learning difficulties who also had a sensory impairment – three were from the same EU funded project [17, 20, 34, 38, 40, 41]. For example, Lanyi *et al.* (2011) describe a project, called 'Game On Extra Time' (GOET), which was an EU funded Leonardo Transfer of Innovation Project. The project supported people with learning difficulties and additional sensory impairments in getting and keeping a job by helping them to learn, via games-based learning; skills that will help them in their working day. The project designed and evaluated ten serious games which aimed to help students to learn how to prepare themselves for work and deal with everyday situations at work such as money management and traveling independently [38].

Age range

Fifteen of the studies focused on children aged 0-12 years old [Articles 1 through to 15]. For example, Vickers *et al.* (2013) describe how they have worked for four years in a UK school to develop accessible serious games for children with physical and cognitive disabilities. They outline a software framework to facilitate dynamic adaptation of computer games to different levels of physical and cognitive abilities. The framework is grounded on a task analysis of gameplay by expert players, and integrates automatic modification of games tasks, interaction techniques, and input device configuration according to a profile of user abilities [5]. Three of the studies focused on adolescents, aged 13-19 [16, 17, 18]. For example, Bonet-Codina *et al.* (2015) describe the development of an application called 'IntegraGame', which was based on a real hostel and designed to teach competencies needed to work in a hostel such as cleaning procedures, vocabulary and social behaviour [17]. Just one study focused on all three age groups [19]; two focused on adolescents and adults [20, 21] and four did not specify the age of their participants [42-45]. Twenty of the studies focused on adults aged 20 or above [articles 22 through to 41]. For example, Wyeth *et al.* (2011, 2015) outline the development of a leisure focused Tangible User Interface they call 'Stomp'. This is a floor-based system that allows users to interact with digital environments by triggering pressure sensors embedded within a 2×3-meter floor mat. The Stomp platform effectively turns the floor into a large, pressure-sensitive computer screen. Stomp can be used by a single participant, pairs, and larger groups. Users interact with experiences through stepping, stomping, pressing, jumping, and sliding [26, 27]. (See Appendix 2 for overview of studies by age).

Technologies

Many of the studies report the design and evaluation of a combination of technologies, rather than a single technology [See for example: 3, 7, 9, 10, 11, 12, 18, 20, 28, 33, 35, 37, 39, 44]. However, in terms of which technologies were the primary or main focus of the project twelve studies focused on mobile devices such as android or smart phones, tablets and IPads [2, 3, 16, 18, 21, 22, 23, 24, 34, 35, 36, 40]. For example, Toshniwal *et al.* (2015) describe a system called 'Vibrein' which has been designed to enrich user interaction with multimedia learning content by making use of different sensors that are available on a mobile device to create an 'intelligent video consumption experience'. 'Vibrein' monitors user attention using the device camera and uses haptic feedback to recapture attention. Rather than touch screen input, it uses tilt in four directions for response to questions [18].

Twelve studies focused on games or serious games [4, 5, 6, 7, 17, 19, 26, 27, 38, 41, 42, 45]. For example, de la Guia *et al.* (2013) provide an overview of a game application they call 'TraInAb' (Training Intellectual Abilities), which is based on Tangible and Distributed User Interfaces and aims to offer an amusing environment focused on the improvement and stimulation of cognitive skills. In the main game an interface is projected on the wall. Users with tangible interfaces, i.e. the objects that integrate RFID (radio frequency identification) tags, can interact with the main interface; this requires the mobile device that incorporates the RFID reader to interact with the main interface and this is necessary to bring objects to the mobile device. For example, if in the game an object must be associated with another, the user only has to bring the corresponding object closer to the mobile device, and then the system recognizes it and displays the outcome of the game [42].

Nine studies in the review focused on the Internet [1, 8, 12, 25, 30, 31, 32, 33, 44]. For example, Cardonha *et al.* (2016) report the development of a web-based authoring tool designed for teachers of students with learning difficulties that enables them to personalise the delivery of courses. In addition, there is a mobile application which the students can use to register and undertake the courses [1].

Three studies report the development of virtual reality applications [3, 9, 39]. For example, Bonarini *et al.* (2015) describe a system that blends full-body interaction, virtual worlds on large screens, motion sensing technology, and mobile robots to support game-based interventions for children with learning difficulties. In regards to the virtual world aspect of the system, on-screen multimedia contents range from very simple coloured shapes integrated with sound or video elements, to 2D and 3D virtual environments and characters that create fantasy tales or communicate specific tasks for the children and the robot, to be performed in the physical world. The virtual representation of the child and the robot (avatars) are body silhouette, mirrored images, or fictitious characters, depending on the current game task. The children interact with multimedia contents on-screen using simple mid-air gestures [3]. Three of the studies focused on software [15, 20, 29]. Two studies focused on augmented reality [14, 37]. Colpani *et al.* (2015) outline a system where the user interacts with the markers in the real world by putting them in front of the webcam, the captured image is processed by the system and the results are displayed on the laptop screen. When choosing a marker and positioning it in front of the camera, the child will have the 3D virtual object superimposed on the marker and its name pronounced by pre-recorded audio. Then a group of words will appear in the screen, and the child must select the correct word regarding that object through the click of the left mouse button or the touchscreen display in the laptop [14]. (See Appendix 3 for overview of studies by technology).

Context or purpose of technology use

In terms of the context or purpose of technology use that was being designed for, the literature review revealed five main uses:

1. Basic educational skills such as literacy, numeracy, colour or shape matching;
2. Leisure and play
3. Cognitive skills training;
4. Way-finding;

5. Vocational training;

Ten studies were developing technologies to teach basic educational skills such as literacy, numeracy and colour recognition [1, 2, 9, 14, 18, 23, 30, 31, 41, 45]. This was across all ages and range of technologies. For example, Perera *et al.* (2012) describe how they developed a range of computer games designed to focus on basic concepts related to colour, number and language [45].

Six studies focused on cognitive skills training across all ages [4, 13, 19, 25, 39, 42]. For example, Fernández-López *et al.* (2013) describe a mobile platform (based on iPad and iPod touch devices), called 'Picaa' designed to present four kinds of educational activities that promote the development of cognitive skills:

- Exploration: templates of multimedia items that let students learn concepts through the navigation of a hypermedia system. Elements can be arranged so that users must navigate through a hypermedia system to create sentences or learn concepts.
- Association: the student must indicate relationships between elements that belong to several sets
- Puzzle: a fragmented image must be rebuilt from multiple pieces. The number and shape of pieces can be configured in the range of 2–25 pieces. The image can also be customized.
- Sorting: a list of elements must be ordered in a sequence [13].

Six studies described developing technologies for leisure or play purposes. [5, 7, 10, 16, 26, 27]. Haworth & Williams (2012) relay how they used Apple IPad or smartphone technology to enable adolescents with learning difficulties to follow trails in a museum by scanning QR codes. Activities were devised which involved users following trails around museum objects, each labelled with a QR code and symbolised text. Visitors scanned the QR codes using a mobile device which then showed more information about an object [16]. Watanabe *et al.* (2014) illustrate how they developed a 'digital dollhouse' with digital sensors and computer graphics with the aim of promoting the play and social skills of children with learning difficulties [10].

Five studies addressed way-finding as an independent living skill. This was for adults only and on mobile devices [22, 24, 35, 34, 40]. For example, Chang & Wang (2010) propose a wayfinding system uses a PDA to provide the signage on the screen in the format of pictures or videos when individuals with cognitive impairments approach decision points. The PDA shows the just-in-time directions and instructions by displaying pictures or videos triggered by Bluetooth beacons sensed by the PDA's built-in reader [35].

Five articles in the review focused on using technology for vocational purposes such as short order food preparation or cleaning a hostel [17, 28, 29, 36, 37]. For example, Chang *et al.* (2015) report on how they designed a system to prompt participants to prepare a meal. The system incorporated a Personal Computer that was employed with an external web camera running an in-house developed Augmented Reality (AR) task prompting software. Open-source AR toolkits were used to identify AR tags deployed in community-based rehabilitation environments. Picture cues of food items for the meal were displayed on the computer screen. To teach participants to acquire the target response, the prompts were presented in a combination of sound and picture cues. By recognizing AR tags that represented food items, the system was able to alert sound cues if food items were incorrect or misplaced [28].

Three studies focused on digital literacy, three on a mix of skills training; three on general independent living skills; two on communication skills and two were rather general or vague in their intended use. (See Appendix 4 for overview of studies by context or purpose).

It is worth noting that two of the studies captured in this literature review developed technology within a museum context [16, 39]. Afonseca *et al.* (2013) explain that their design project is the result of a join initiative with the Madeira Whale Museum. The museum's mission is to preserve the history of whale hunting in the island of Madeira as well as to educate, protect and promote activities about sea life and its preservation. Therefore it was in this cultural educational context that they developed a Virtual Reality interactive tool. The tool builds on motivating game-like experiences, supports collaborative learning, and uses VR to personalize the learning process [39].

What common design principles can be distilled from the literature?

Once the 45 papers had been identified, they were each re-read and notes were made on anything within the paper that had implications for technology design. These notes were then analysed both inductively (bottom-up, drawn from the information within the articles) and deductively (top-down, influenced by pre-published principles such as those for accessibility and usability). This dual-process was adopted in order to identify common ideas or recommendations that could be clustered together. This process produced five main categories of design principles:

1. Learning Support (29 papers);
2. Accessibility (19 papers);
3. Usability (16 papers);
4. Tailor-ability (14 papers);
5. Agency (13 papers);

The labels given these categories (and sub-categories) are not necessarily those used by the authors themselves. The five main categories are outlined and exemplified in Tables 2-6 along with indications of which of the 45 papers, referenced each principle. To be included, a principle needed to described or recommended by ten or more of the 45 papers. To be included, a sub-category of a principle needed to be described or recommended by three of more of the 45 papers (range=3-15).

Learning Support

The first design principle that we distilled from the 45 papers within this literature review is one that we have called 'Learning Support'. Learning Support design principles essentially focus on enhancing the learning experience or making learning more likely to happen. This is the most prominent design principle that we have identified in relation to the number of sub categories and examples we have identified. (See Tables 2.1,2.2 and 2.3). Six sub-categories were identified each of which have particular pertinence for people with differences and difficulties associated with perception, memory and cognition:

1. Feedback and reinforcement
2. Associability

3. Familiarity
4. Focus
5. Facilitation
6. Appropriate Challenge

Feedback and reinforcement design principles focus on helping users to succeed and avoiding where possible the potentially negative consequences of failing on a task. The design principle of Associability is pertinent as it can be difficult for people with learning difficulties to understand key concepts and establish associations between the computer world and the real world. Using icons, tasks and materials that users are familiar with can reinforce learning or memory of tasks. Many people with learning difficulties find it difficult to concentrate for long periods of time, Focus is therefore an important design principle in terms of seeking to maximise attention on a task or bring attention back to a task. Facilitation as a design principle relates to the instructions and prompts that an application or game provide a user with learning difficulties. For example, providing multi-sensory instructions, or just-in-time prompts. The final principle ‘Appropriate Challenge’ essentially focuses on not making the activities within an application too hard or easy and allowing opportunities for consolidation of learning, for example enabling the user to repeat an action as many times as they wish. (See Tables 2.1, 2.2 and 2.3 for more examples).

Accessibility

Many papers mentioned accessibility when discussing the design of their technologies and although not always explicitly mentioned; the principles they articulated could be categorised using the POUR model that underpins the Word Wide Web Consortium (W3C) guidelines on accessibility[3]:

1. *Perceivable* - Information and user interface components must be presentable to users in ways they can perceive: this means that users must be able to perceive the information being presented (it can't be invisible to all of their senses)
2. *Operable* - User interface components and navigation must be operable: this means that users must be able to operate the interface (the interface cannot require interaction that a user cannot perform)
3. *Understandable* - Information and the operation of user interface must be understandable: this means that users must be able to understand the information as well as the operation of the user interface (the content or operation cannot be beyond their understanding)
4. *Robust* - Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies: this means that users must be able to access the content as technologies advance (as technologies and user agents evolve, the content should remain accessible)

In order for technologies to be ‘Perceivable’ they must be designed to be adaptable- presenting content in different ways and anything presented to the user must be distinguishable so that users can recognise the difference between one thing and another. For example, ensuring sufficient contrast so that it is easier to distinguish items, both visual and auditory. (See Table 3 for further examples).

[3] https://www.w3.org/TR/UNDERSTANDING-WCAG20/intro.html

People with learning difficulties do not always like completing tasks under time pressure. The default time limits on solving a problem, pre-set on many educational software or game Web sites therefore can be too short. Therefore technologies need to be ‘Operable’, in that they are designed to allow enough time for users with learning difficulties to complete tasks. Operability is also influenced by the extent to which users with learning difficulties are helped to navigate through a program, system or game. For example helping users to find content and know where they are by placing navigation information in the same place (usually at the top), ensuring that it is consistent and simple, using maps when appropriate, using home and back buttons and providing auditory context and orientation information. (See Table 3 for further examples).

In order to meet the requirements of the ‘Understand-ability’ design principle technologies and associated content must be readable and predictable. For individuals with learning difficulties, the information presented to them when using computers can be too overwhelming to handle; readability is therefore important. Examples of how readability can be enhanced include: making any text plain text (rather than images or graphics), avoiding dense blocks of text and using plain language. (See Table 2 for further examples). Predictability is also a key component of ‘Understand-ability’ in that users with learning difficulties tend to respond well when they can learn a pattern or sequence of actions and can struggle if this pattern is interrupted by unexpected occurrences that they are unable to problem-solve. Predictability requires organisation to be maintained so that instructions and buttons are clearly displayed and in the same place (often at top) throughout presentations. (See Table 3 for further examples).

In order for technologies and systems to be ‘Robust’ they need to be consistent and error-free as well as usable with one or more assistive technology (i.e. input from a range of sources is catered for). See Table 3 for further examples).

Whilst accessibility principles are valid design principles, they tend to be universal and not particularly unique to learning difficulties. Having said that Distinguishability and Readability are two of the most frequently mentioned principles within this category and particularly reflect the perceptual and cognitive differences and difficulties that people with learning difficulties can experience.

Usability

Within the computer-science and HCI fields, Usability is about making technologies and applications easy for people to use, whilst Accessibility focuses on making them equally easy for disabled people to use. (Seale, 2006). Usability tends to have a broader definition than accessibility; encompassing issues such as the effectiveness, efficiency and satisfaction with which users can achieve their goals. Whilst many papers in the literature review mentioned design characteristics that could be associated with Usability; very few referred to all the common Usability principles such as those proposed by Nielsen (2012): Learnability, Efficiency, Memorability, Errors and Satisfaction. Rather, two principles that we have called 'Simplicity and 'Efficiency' emerge which appear to have particular pertinence for people with learning difficulties. The Simplicity principle focuses on reducing clutter and eliminating any unnecessary or irrelevant elements that might distract focus. For example, using clear graphics and icons, simple screen layout, consistency, contrasting colours, and large, clear navigation buttons, descriptive hyperlinks, minimizing scrolling and limiting the number of fonts. (See Table 4 for more examples). The Efficiency principle is about reducing the work-load for the user for example using supportive automation to make the user's work easier, simpler or faster or allowing changes to content quickly and easily without need for long complicated operations. (See Table 4 for more examples).

Table 2.1: Learning support design principles: Feedback and Reinforcement

Category	Sub category	Examples	Papers
Feedback and Reinforcement	**Multi-sensory**	When users make a selection (right or wrong) after a prompt, they are given a learning reinforcer: an audio clip saying the name of the selection. When users follow prompts correctly, they are given two positive reinforcers: an audio clip saying "Good Job!" or "That's right!" and a picture of something they might like.	3,6,7,13,17,31
		Students with impairments often have communication difficulties at both vocabulary and comprehension levels so sounds are also used to give reinforcement to the user about his actions. These sounds could be also recorded or synthesized using text-to-speech	
		The system also includes an interactive interface with audio and video feedback to enhance students' motivation, interest, and perseverance to engage in training sessions.	
		Reinforce positive feedback, by means of laughs, applause, dancing, etc., and not only by spoken words.	
	Emotional and encouraging	Feedback should be emotional: e.g. appearing sad for negative feedback, and laughing and dancing for positive feedback	7,17
		The style is friendly and encouraging with positive messages also in case of failure.	
	Avoid negative feedback-the system should help users learn from their mistakes and not punish them.	Give positive messages on failure	3,14,17,31
		When users do not follow a prompt correctly during an activity, give them various attempts and hints on how to follow prompts correctly along with learning reinforcers which also help users learn the correct response. On the last attempt, give users no other choice but to follow the prompt correctly and learn the correct response.	
		The screen visual/audio contents should offer positive reinforcement to a successful action, and have no reaction in case of failure.	
		Only correct actions are available at each moment of the game.	
		Only objects related with the next correct action are selectable at each moment of the game in order to provide an error-free play.	
	Informative	Leave users in do doubt of correct answer: Users may not really know whether they have completed a task or not-This may explains why they so frequently but unnecessarily persist with tasks. Therefore, more attention should be paid by game developers to ensure children understand the game.	7,30,31
		Display progress information: Users should know which round they are on out of the total number of rounds in an activity	

Table 2.2: Learning support design principles: Associability, Familiarity, Focus

Category	Sub category	Examples	Papers
Associability	**Where possible use images of the real thing rather than abstract representations of the object**	Provide context sensitive in situ instructions The use of concrete material enables students to establish relationships between the experienced situations and the abstraction of the studied concepts. The representation of money amounts through images of bills and coins	3,8,10,12,14,16,21,31, 41
Familiarity	**Build in familiarisation tasks**	Unfamiliarity with the icons can cause problems, therefore provide participants with hints about the possible location or shape of icon(s). A familiarization task is set up to train selection and navigation in the same environment	17,36
	Make use of familiar situated material	Only use very familiar icons Use pictures of things users like as positive reinforcers. The learning experience should make use of contents users like and are familiar with, e.g., music, videos, stories, voices of relatives, or images of known environments or situations. This makes learning more "situated" and is a means for consolidation, as discussed below.	3,11,32,45
Focus	**Maximise attention on the task**	Most users with learning difficulties have limited capability of concentration, therefore, each activity should be designed to be relatively short (3-5 minutes) Screen just contains a single task at a time Actions are implemented at different levels of detail. If the focus of the exercise is on the order of the actions and not on how they are done, a single click or touch is sufficient to do them. However, if the focus is put on how to do the action, then the action is broken into a sequence of steps, each one launched through a new interaction. By removing physically demanding interaction tasks, such as moving a pointer quickly over a large screen area, the user can focus on the intellectually challenging parts of the game. Therefore automating some elements of gameplay can enable participation Capture attention: Stimuli should act as behaviour-eliciting agents that attract attention, stimulate action and promote engagement.	3,5,13,14,17,37
	Bring attention back to the task	If the user starts to look somewhere else rather than at the mobile screen, the front camera of the mobile detects this activity and vibrates the phone to bring the user attention back to the screen. The basic and essential information is complemented with motivation or call attention messages (voice), such as "Congratulations,' "it goes like this" or "be more attentive". Remind user of the task: Problems with working memory can impair the understanding of screen information and recall of the current task context. This should be accounted for in design, for example by using simplified screen layouts and system initiatives to remind of and help recapture the task context and provide visible systems status information.	18,19,20

Table 2.3: Learning support design principles: Facilitation, Appropriate Challenge

Category	Sub category	Examples	Papers
Facilitation	**Instructions- multisensory**	Instructions are provided always verbally, with a simple and clear style optionally complemented with a written message to reinforce reading skills of users that have them. In addition, in addition iconic images of the objects to be collected are shown at a side of the screen to reinforce the verbal and written messages.	14,17,37
		Provide voice instructions in order to improve the understanding of children, especially those who cannot read.	
		To teach participants to acquire the target response, the prompts were presented in a combination of sound and picture cues	
	Prompts	Just in time prompts- By bringing context awareness to handheld prompting devices and reducing cognitive load; people with cognitive impairments can have the prompting experiences in easier and more comfortable ways.	3,28,35
Appropriate Challenge	**No prior knowledge needed**	Do not rely on the acquisition of specific competencies before interaction and engagement can occur.	26,27,42
	Scaffolding	Ensure a balance between success and challenge. E.g. Systems for new route learning using location based services can be appropriately structured to heavily scaffold the planning of new routes and the first instances of traveling these new routes and then be programmed to offer less intervention as the user develops the confidence and skills to ultimately travel these routes independently	11,25,40
		The proposed tasks should be "sufficiently" challenging, without being discouragingly hard or boringly easy; they should progress through increasing levels of difficulty as the experiences unfold.	
	Consolidation	Create new challenges but also include moments of consolidation	11,16,18
		Evaluate the learning by asking questions about the content and automatically force-rewinds to the location where the concept was explained if the user answers incorrectly.	
		Allowing those with learning difficulties to repeatedly listen to an item independently or view a video several times.	
		Most disabled children have limited long term memory and experience the difficulty of retaining a learned concept or skill from one session to the next one. It is necessary to design activities that on the one end introduce novelty and create new challenges, and on the other end include moments in which children repeat and consolidate what they have previously understood.	

Table 3: Accessibility related design principles

Category	Sub category	Examples	Papers
Perceivable	**Adaptable**	Provide text equivalents for non-text content, including auditory and visual components, so that it can be changed into other forms people need, such as Braille, speech, symbols, other languages including sign language. Provide audio with text.	19,20,40, 45
		Adjustable display image size should be offered, with appropriate labelling for icons, with combined use of pictures and audio prompts for navigation, and in general multisensory presentation of feedback information.	
	Distinguishable	Never convey information by colour alone. Ensure sufficient contrast so that it is easier to distinguish items, both visual and auditory.	3,31,34,38,40,41
		Highlight with colour-blind-friendly colours (yellow), use a high-contrast colour-scheme (white on black), use practical fonts (e.g., easily readable), use good quality images and make choices (i.e., the numbers, shapes, colours, and images of objects) sufficiently large to make them accessible to users with visual and motor impairments.	
		Labels should be situated above their fields so that blind people to find the right element. In the style-definition text and background colours, padding, text-size and contrast are described.	
Operable	**Allow enough time**	The system ensures that if users are distracted by other activities, they are informed that the system is still waiting for their interaction before terminating the session.	31,38,40,41,45
		Games should be interactive, flexible and should be in an appropriate speed, since users with learning difficulties can be very slow in their performance and responding.	
	Navigable	Employ visual cues to help users with navigation through the system.	17,32,34,38,40
		A minimum size of at least 9mm for all clickable elements should be given. Also an empty area surrounding these elements is very important. The buttons should be placed where everyone can reach them easily.	
		Place navigation information in the same place (usually at the top) and ensuring that it is consistent and simple, using maps when appropriate, using home and back buttons, providing context and orientation information	
		Navigation is disabled when it is not necessary, In other tasks, navigation is automatic- using a single click.	
Understandable	**Readable**	Not too much text (information).	3,8,32,38,40,41,45
		Language used is as simple as possible, with short sentences and max. 70 characters pro line.	
		Make any text plain text (rather than images or graphics), no dense blocks of text, plain English.	
	Predictable	Consistent, simple screen layout.	20,34,38,40,41
		Maintain organisation - instructions, buttons, clearly displayed and in the same place (often at top)	
		The input features should remain consistent throughout the application.	
Robust	**Error-free**	Checkboxes and radio buttons make it possible that the text inputs for users are reduced and thereby also the error rate is lowered. If textual input is really necessary, a suitable keyboard layout is essential.	34,36,38,40,41
		Use fall-backs.	
	Compatible	Aim for compatibility with assistive technologies - e.g., screen-readers, text-to-speech, zoom features.	5,7,15,26,27,33,40,42,44
		Creating middleware that translates the input from access devices such as eye gaze into mouse and keyboard strokes that the games can process.	

Table 4: Usability related design principles

Category	Examples	Papers
Simplicity	Avoid unnecessary buttons, sounds, and distracting objects	11,14,19,20,28,29,31,38,40,41,45
	Regarding the interaction between the user and the game develop simple and clearly organized interfaces. Every input by the user corresponds to actions duly identified on the screen	
	Use clear graphics and icons, simple screen layout, consistency, contrasting colours, and large, clear navigation buttons, descriptive hyperlinks, minimizing scrolling and limiting number of font	
	Customization should be so simple that inexperienced users e.g., teachers, educators, therapists can autonomously achieve it.	
Efficiency	Allow changes to content quickly and easily without need for long complicated operations.	5,13,17,18,20,32
	One click/touch interaction: the game can be played with a mouse, based on one-button click and mouse movement or on a touch screen. Clicks or single touches are interpreted as selections. Camera rotation is handled either with mouse movements or with touches in a navigation widget that frames the scenario. Actions are generally launched with a single click or a mouse or finger movement.	
	Allowing users to provide input by just tapping the screen (no dragging or swiping) to make them accessible to users with motor disabilities.	
	The interface uses as few elements as possible.	
	Mobile device uses tilt in four directions for response to questions, since touch, as a modality on mobile devices requires fine motor skills.	
	For input, the sequences of actions should be simplified and available choices limited when practical, and direct selection techniques favoured to support simple, time-independent actions.	

Tailor-ability

Within the papers reviewed there were a set of papers that talked about personalisation. For the purposes of this review, we have chosen to re-label this as 'Tailor-ability'. Our justification for doing so, rests largely on our concern that 'personalisation' might be misunderstood as the actual user of technology having the opportunity to personalise an application or game to suit their preferences. However, within the context of the literature review, personalisation was typically understood as somebody other than the person with a learning difficulty customising an application or monitoring performance within an application. This person was usually a parent or teacher. Related to this, a small handful of studies, described how their designs met an 'Adaptivity' principle, where the learning activities and scenarios are automatically tailored to users' needs based on pre-programmed user profiles. (See Table 5 for examples). Within the context of the ARCHES project and its aims of promoting inclusion, we are more interested in the fourth set of principles, focused on agency.

Agency

A number of papers referred to design principles that we felt could be categorised as relating to agency: enabling the user with a learning difficulty to be an active agent in their own learning. Within this category, we identified a self-pacing principle related to enabling users to control the speed with which they progress through an application, including the opportunity to go back and revisit actions or items if needed. A second principle we identified related to enabling users to indicate choice and preferences (as opposed to a teacher or parent). For example, giving users the freedom to edit pictures or pictograms being used within the application or game. In their daily lives people with learning difficulties are infrequently encouraged to take the initiative, and therefore can have little personal motivation to engage with technology based tasks and activities. We therefore felt it particularly pertinent that a design principle focused on allowing the user to take the initiative and promoting proactive interactions was identified in the literature. (See Table 6 for examples).

Table 5: Tailor-ability related design principles

Category	Sub category	Examples	Papers
Can be tailored or customised by a parent or teacher	**The teacher or therapists can customise the game or app to users' needs**	The Web portal is targeted at instructors and offers functionalities of course management through which courses are created and edited; and student management through which students are registered in the platform and enrolled in courses. Instructors assign a 'tag' to each student, representing the accessibility support she might need and students are not able to visualize or edit the tag that instructors assign to them;	1,2,6,9,11,18,23,24
	The teacher or therapist can supervise or monitor users performance	Involves the parents in the teaching process through the automatic delivery of SMS/Email and remote website access to track the students' performance and give feedback on their personalized plan.	12,22,25
		Learning analytics are incorporated in the platform for easy monitoring of student progress via Web interfaces. To easily assess the subjects' learning trend and refine training programs, a dashboard is created.	
Can be automatically tailored by the technology	**Adaptive user interface/ Adaptivity**	A system that generates learning scenarios keeping into account the user's profile and their learning objectives. The user's profile is used to represent the cognitive abilities and the domain competences of the user. The system also records the user's activities during his/her interaction with the Serious Game and represents them in interaction traces. These traces are used as knowledge sources in the generation of learning scenarios.	4,5,43
		Following the task analysis process, the resulting game task data can be used to define the properties and requirements for each game task and input device. Then, by generating a user profile we can learn how best to consider each user in terms of the task that is to be performed and the most appropriate way to perform it.	

Table 6: Agency Design Principle

Category	Examples	Papers
Self-pacing	Allow users to control the speed at which they move through the game or app	18,23,38,39,40,41
	Allow users to go back - essential for all users, and especially those who may have organisational, information processing and/or memory difficulties	
	During this process, users are always allowed to switch back and forth between cameras as many times as needed to complete the task. On completion of all correct name associations, the user advances to the next phase.	
Enable users to indicate choice and preferences	Freedom to choose and edits pictures or pictograms being used within the app/game	16,17,35,40
	A layered approach to information access is adopted with the first layer comprising a label, the second a mobile-web enabled screen and the third choices of text, pictures, video and audio	
	Users can define their choices in the profiles. For example, users who are blind or with low vision may choose to avoid taking stairways in a wayfinding app, although they may be capable of doing so.	
	Allow User Control - allow for user customisation based on user preference; for example, some users may wish to slow things down, or to use keyboard access	
Promote proactive interactions- allow the user to take the initiative	Allow exploration: e.g. By selecting different buttons or options, the user can explore the learning environment and discover content or experiences for themselves. This process is open ended, and the user can take as long as he/she needs to explore.	13,39,27
	There is no cognitive barrier to becoming engaged with an activity. Such behaviour is exploratory, as it allows people to develop an understanding of the system through action, observation, and reaction. Designing for autonomy support ensures that experiences provide choice, minimize pressure to perform in specified ways, and encourage initiation	

How were the design principles derived or evidenced within the literature?

If the design principles we have identified through our literature review are going to influence the practice of the technology partners in the Arches project and technology developers beyond the Arches project, we need to have confidence that they are underpinned by some degree of evidence or justification. Therefore we have examined the corpus of 45 papers to identify whether and how their design principles were derived or evidenced. Some papers were very explicit in their articulation and justification of design principles (typically called, design priorities, design heuristics or guidelines). Other papers did not explicitly present or distil out design principles from their work, but implications and assumptions about what they might be could be drawn from their descriptions of the work done. The papers that were more explicit in their articulation of design principles, fell into four broad categories in relation to how these principles were derived.

1. No explicit or direct evidence to support proposed design principles;
2. Discussion with parents, teachers and other professionals to identify design priorities;
3. Reference to existing principles or guidelines in related fields;
4. Use of other studies and literature to justify design principles.

No explicit or direct evidence

Examples of papers that offered no explicit or direct evidence to support their design principles are articles [7] [11] [12] and [17]. Marco *et al.* (2013) write about how: “The principles of universal accessibility have made possible a great advance in the application of digital technologies to the learning of disabled children” but do not explicate the principles or offer any references to them [7]. Garzotto & Bordogna (2010) write in an authoritative manner on principles of consolidation, engagement and the use of familiar material, but again offer no references or evidence to justify their identification [11]. Saleh *et al.* (2013) write about an ‘Accessibility standard (web) for MID and MLD’ but offer no reference. After this identification they list a number of vague guidelines such as: access to relevant data; good general set-up; appropriate inclusion of graphics and learning object; robust pedagogical support; readability of text and appropriateness of activities [12]. Bonet-Codina *et al.* (2015) talk about an ‘error-free pedagogical approach’; but similarly offer no references or evidence to justify the use of such an approach [17].

By cross-checking the identified principles against these four papers we can see that the validity of three sub-categories of design principle are now in question: emotional and encouraging feedback and informative feedback (which are sub categories of the feedback and reinforcement principle, which itself is a sub category of the learning support design principle) and building in familiarity tasks (which is a sub category of the familiarity principle, which itself is a sub category of the learning support principle). If these studies are excluded, the threshold for being considered as a commonly mentioned principle (mentioned by three or more studies) is not met, Furthermore, given that each of these principles fall within the ‘Learning Support’ design principle, its overall validity could be called into question. However, given that Learning Support is a ‘large’ principle which is frequently mentioned by other papers that have provided evidence, we are confident that this principle as a whole has merit. (See Tables 2.1. 2.2 and 2.3).

Discussion with parents, teachers and other professionals

Examples of papers that identified design priorities following discussions with parents, teachers and other professionals are articles [3] [14] and [31]. For example, Bonarini *et al.* (2015) identified a set of fine-grained functional and non-functional requirements for their design of robots and virtual worlds following discussions with specialists. These requirements included the need to build familiarity and trust, feedback, reward, prompts, instruction and facilitation [3].

Reference to existing principles or guidelines

A number of papers made reference to usability, accessibility or other kinds of guidelines within their literature reviews or description of the design of their own technologies. Examples of papers that made reference to existing usability principles or guidelines in related fields include articles [20], [21], [34], [38] and [40]. Keskinen *et al.* (2012) make reference to 'general user interaction design principles' that highlight the need for: 'simplicity, clarity and use of familiar, real life metaphors' [20]. Alfredo *et al.* (2015) draw on the five components of Usability proposed by Nielsen (2012): Learnability, Efficiency, Memorability, Errors and Satisfaction [21].

Krainz *et al.* (2016) make reference to the W3C accessibility guidelines which are underpinned by four principles: Perceivable, Operable, Understandable and Robust [34]. Brown *et al.* (2011) describe how they reviewed a range of accessibility related design guidelines aimed as users with multiple cognitive and sensory impairments including those proposed by W3C, TechDis and the British Dyslexia Association [40]. They then explain that after reviewing these guidelines with trainers from two user-representative organizations they derived 13 additional design requirements which included: i) allowing users to go back, especially those who may have organisational, information processing and/or memory difficulties; ii) allowing for user customisation based on user preference iii) helping users navigate, find content and know where they are by placing navigation information in the same place (usually at the top) and ensuring that it is consistent and simple, using maps when appropriate, using home and back buttons, providing context and orientation information and iv) maintaining organisation by having instructions, buttons, clearly displayed and in the same place (often at top) throughout presentations.

Lanyi *et al.* (2011) make reference to the work of Desurvie and Wiburg (2008) in outlining what they call 'Game Approachability Principles' (GAP) for Improving Game Approachability which include: players not being penalized repetitively for the same failure; varying activities and pacing during the game to minimize fatigue or boredom [38]. Colpani *et al.* cite the work of Piaget to justify building in concrete material into the application to enable students to establish relationships between the experienced situations and the abstraction of the studied concepts [14].

Use of other studies and literature

An examination of the literature referenced by the papers in the corpus under review in this report revealed some common topics or issues. For example, there were a large number of references to literature that focused on the description and diagnosis of difficulties (labelled conditions) as well as papers reporting quasi-experimental studies that were attempting to evidence improvements on various measures when users engage with technologies compared to control groups. With regards to literature that was being cited in support of design principles, this fell into three broad categories:

1. Understanding user requirements
2. Observing use of technologies
3. Accessibility and Usability

Understanding user requirements

Three of the most cited papers within the corpus report on the results of surveys of users with learning difficulties or their families. (Dawe, 2006; Dawe 2007; Feng *et al.* 2008). The focus of the surveys is the role that technology plays in the lives of people with learning difficulties and patterns of their technology use. The researchers use the results to suggest implications for technology design. Dawe (2006) reports on the results of semi-structured interviews with twelve families about how and why they acquire and abandon assistive technologies. The results lead Dawe to suggest some design implications which include the importance of simplicity not only in technology function but in configuration, documentation, maintenance, and upgrade or replacement [referenced by studies 8, 12, 20, 27, 29, 36]. Dawe (2007) reports on the results of semi-structured interviews with five families to understand current patterns of mobile phone use among young adults with learning difficulties. Dawe identified that requirements include the need for a simplified navigation menu with fewer options and a rugged handset and charger input. [Referenced by studies 8, 26, 27]. Feng *et al.* (2008) discuss the results of an online survey that investigated how children and young adults with Down syndrome use computers and computer-related devices. The survey responses cover 561 individuals with Down syndrome between the age of four to 21. The survey results revealed aspects that the respondents found easy and difficult about computer use. For example, the majority of the 561 children and young adults with Down syndrome surveyed could use the mouse to interact with computers, which requires spatial, cognitive, and fine motor skills that were previously believed to be quite challenging for individuals with Down syndrome. However, the results also showed great difficulty in text entry using keyboards. [Referenced by studies 8, 29, 36].

Observing use of technologies

There were slightly more papers cited across the corpus where the focus of the work was observing how people with learning difficulties use technology. For example, Saridaki & Mourlas (2011) present a series of observations made by researchers and educators on the motivational impact of games on the educational experience of users with learning difficulties [cited by 44]. Based on their observations of how the users appropriated the camcorders they argue for greater recognition of the different ways in which they may choose to make a technology 'mundane' (normal and easy to use) for them. Williams & Hanson-Baldauf (2010) present a study designed to assess how people with learning difficulties used a web portal designed specifically for them. They noted aspects that the users struggled with, which has implications for future design work such as participant difficulty with advanced navigation skills and eye–hand coordination connected to directed cursor movement and mouse manipulation; and web content readability levels [cited by 16]. O'Connor & Fitzpatrick (2010) draw upon the results of a year-long participant observation study of the use of camcorders by six adults with learning difficulties [cited by 26, 27].

The most cited papers were those by Kirijian & Myers (2007) and Loyd *et al.* (2006). Kirijian & Myers (2007) report on a project that aimed to develop online learning modules and games for individuals with Down syndrome [cited by 8, 25, 29, 36]. The first two phases involved literature reviewing and interviews with experts. What is most interesting about this project however, is that in the third phase (during usability testing) phase, the researchers found results that contradicted those found in the earlier phases. For example, contrary to the research the researchers had completed prior to the usability study no preference for the Comics Sans Serif style font was found. They conclude that the repeated use of this font in materials designed for people with Down syndrome should perhaps be questioned. Kirijian & Myers report a number of other observations regarding Font, Colours and Buttons. For example with regards to buttons, they note that:

- Users favoured clicking the largest button on the page.
- Users were interested in clicking more on buttons with a dark background colour and light text on top (high contrast).
- Buttons that make it clear what the user is to do scored very well. When it was clear the object was a button and/or the clickable area was shown, the button was more popular.
- Buttons with a clear clickable area (an outline shape) were popular. Framed buttons were preferred to floating buttons (e.g. underlines).
- Buttons with arrows pointing towards them were very popular.
- No clear findings on preference for button location (spatial preference).

Lloyd *et al.* (2006) report on a project called LATCH-ON which supported the use of computers by young adults with learning difficulties [cited by 8, 12, 29]. They explain how they have used their experience of working on the project for six years to develop a check-list for evaluating the design of software. This checklist suggests a range of aspects that technology developers can attend to including:

- Instructions are clear easy to understand and age appropriate
- Help messages are easy to access
- Appropriate screen formatting
- Feedback is appropriate and relevant
- Multiple levels of mastery
- Appropriate cues and prompts to responses

Studies that report a focus on accessibility and usability

Nour (2015) cites the work of Borg *et al*. (2014) who conducted a literature review in order to identify and synthesize methods for measuring the accessibility of 'electronic communication for people with cognitive disabilities' [33]. Borg *et al.* concludes that:

> *Although thin, the current evidence base indicates that the accessibility needs, requirements, and preferences of people with cognitive disabilities are diverse. This ought to be reflected in accessibility guidelines and standards.*

Vickers *et al.* (2013) cite ten references of studies looking at accessible game design that they encompass into a Game Accessibility Development Framework [5]. Erazo & Zimmerman (2015) reference four articles about web accessibility and cognitive accessibility that implicitly appear to underpin their design principles which include: the use of focused tasks i.e. the screen just contains a single task at a time; language used is as simple as possible, with short sentences and max. 70 characters pro line and the interface uses as few elements as possible and employs visual cues to help users with navigation through the system [32]. Three studies within the corpus [38,40, 41] cite a book chapter written by Brown *et al.* (2010) which seeks to explicate accessibility guidelines derived from their work designing serious games for people with learning and sensory difficulties.

In addition to referencing studies that talk mainly about accessibility design issues, the corpus also referenced studies that addressed both usability and accessibility issues. For example, Kultsova *et al.* (2016) references the work of Dekelever *et al.* 2015 who analyses classifications of intellectual and developmental disabilities and the extent to which mobile software design addresses the usability and accessibility requirements suggested by these classifications [24]. Dekelever *et al.* 2015 make a number of design recommendations in relation to navigation and graphic design; text requirements and personalisation including:

- User input should be minimized;
- The user interface should have consistent and simple structure;
- The mobile application should be equipped to identify and prevent errors
- In order to reduce the cognitive load and a better understanding, related images can be used;
- The menu of the mobile device should be adjustable so it can adapt to the needs of users;
- The number of functions should be limited in order to avoid cognitive overload.

Haworth & Williams (2012) reference two of their own papers to support their design decisions [16]. One paper by Williams (2012) described a method for testing both usability and accessibility of websites by people with learning difficulties. Williams concludes that virtually all of the usability and accessibility issues that were elicited could be solved by careful layout redesign (larger menu images; the greater separation of text and audio link 'hot spots') and more appropriate input devices for those who have difficulties manipulating the mouse.

Three studies in the corpus cite the work of Lanyi *et al*. (2010) who report on the design and development of serious games for people with learning disabilities and additional sensory impairments. Lanyi *et al.* (2010) argue that it is necessary to design the user interfaces for maximum accessibility and usability in order to minimise the additional cognitive load placed on the user while navigating within the software. In order to achieve these goals, Lanyi *et al.* explain that they have followed published design guidelines, and placed emphasis on using graphics, animations and auditory output to promote user engagement and provide alternatives to text [cited by 19, 38, 41].

What factors might influence the application of the identified design principles

Given that the Arches project is developing technology for a particular age group (adults); with particular technologies in mind (virtual or augmented reality applications, 3D haptic devices and serious game applications) and for a particular context (cultural and heritage sites) one of the things we were interested in assessing was whether there was a relationship between the kinds of design principles employed by the technology developers and:

- The age of the participants;
- The technology being used;
- The context in which the technology was being used.

In order to assess this, we used frequency data, the number of times a particular criteria was identified across the corpus of 45 papers (where a criteria could be mentioned more than once within one article with different examples of how it was being addressed). Whilst this is a very crude assessment it does potentially offer a useful insight into the design activities of technology developers that may warrant further investigation.

Are some design principles more age specific than others?

From Table 7 we can see that there is a tendency not to design for agency when developing technologies for children and adolescents. This is counterbalanced by the fact that some developers are building tailor-ability into technologies for adults with learning difficulties, where the power to control aspects of the application is in the hands of others. We would question the desirability of utilising this design principle however, within the Arches project given the projects intention to focus on inclusion. It is also interesting, but perhaps concerning that accessibility does not seem to be a major concern when designing for children or adolescents with learning difficulties.

Table 7: Design principles by age

Age	Learning Support	Accessibility	Usability	Tailor-ability	Agency
Children	24	6	4	8	1
Adults	16	31	6	4	9
Adolescents	9	1	2	0	2
Adolescents and adults	2	2	2	0	0
Unspecified	2	5	1	1	0
Children, adolescents and adults	1	1	1	0	0
Totals	54	46	16	13	12

Are some design principles more technology specific than others?

From Table 8 we can see that the Accessibility and Learning Support design principles are more prevalent when designing for games, mobile devices, and the Internet. It is not surprising that Agency is a key design principle when developing technologies that promote independence, such as mobile devices; however it is perhaps surprising that the Internet is a not a focus for agentic use.

Table 8: Design principles by technology

Technology	Learning Support	Accessibility	Usability	Tailor-ability	Agency
Games	15	20	6	3	4
Internet	11	8	2	3	0
Mobile Device	9	12	3	4	6
Other	7	1	1	2	0
Virtual Reality	6	1	0	1	2
Augmented Reality	4	1	0	0	0
Software	1	3	3	0	0
Totals	54	46	16	13	12

Are some principles more context specific than others?

The data in Table 9 suggests that, broadly speaking, there are no particular design principles that are more context specific than others. They appear to be spread across the different contexts of use. The one exception to this is the dominance of the Accessibility principle when designing for independent living (general and way-finding). This has relevance for the Arches project in that it is highly probable that a key aspect of promoting the inclusion of people with learning difficulties in cultural and heritage sites will be supporting them to find their way around buildings which often have complex layouts.

Table 9: Design principles by context

Context	Learning Support	Accessibility	Usability	Tailorability	Agency
Education- Basic Skills	12	10	5	4	2
Skills Training (Mixed)	12	2	1	2	0
Leisure & Play	9	4	1	1	2
Vocational	8	2	2	0	1
Cognitive Skills	5	2	2	2	3
General independent Living	3	8	2	1	1
Independent Living-Wayfinding	2	12	1	2	3
Digital Literacy	1	3	0	0	0
Communication Skills	1	2	2	1	0
Other	1	1	0	0	0
Totals	54	46	16	13	12

DISCUSSION

The purpose of the literature review presented in this report has been to distil out common design principles from the literature that might inform the work of the technical partners within the ARCHES project. In this section we will propose an overarching framework for these principles which has the potential to guide design and development practice in the field of learning difficulties, technology and heritage and culture.

Scoping the parameters of a design framework

In our exploration of a potential framework for design principles around which technology design and development practice can be built we will begin by making a case for postponing the inclusion of the tailor-ability principle. We will then discuss how a diversity and difference dimension and a digital inclusion dimension can underpin our proposed design framework.

A case for postponing inclusion of the tailor-ability principle

The Tailor-ability design principle essentially focuses on enabling powerful 'others' such as parents, teachers, or carers (support workers) to mediate how people with learning difficulties access and use their technologies. It is our contention however, that Tailor-ability is not unproblematic and that the philosophy underpinning the principle as well as the potential processes and outcomes of implementing the principle need to be unpacked and examined in much more detail before being accepted and implemented in practice. Our justification for making this case is that there is a growing amount of evidence to suggest that support workers may not be totally influenced by the best interests of the person with a learning difficulty when mediating access. For example, Seale (2014) examined the role that supporters play in facilitating access to and use of technologies by people with learning difficulties and the extent to which this role is influenced by perceptions of and responses to risk. In her examination, Seale argued that the growing dominance of safe-guarding and protective discourses has meant that issues of risk and safety are emerging as factors that have a significant influence on the way that that people with learning difficulties are supported to use technologies. In particular she warns that one consequence of the desire to minimise risk is a growing tendency by support workers to prevent access to or hinder meaningful use of technologies. In other words, as well as preventing potentially harmful situations from happening through the use of technologies, they also prevent potentially beneficial ones, thus denying opportunities for inclusion. Seale and Chadwick (in press) present a more recent review of the literature in relation to risk and Internet use by people with learning difficulties and extend the arguments of Seale to contend that more research is needed to capture the lived experience of both people with learning difficulties and their support workers in order to understand how perceptions of risk and what it means to lead a normal life in a digital society intersect with perceptions of rights and what it means to be human. Such research has implications for how technology developers design technologies to enable support workers and people with learning difficulties negotiate how to balance the risks and opportunities that technologies offer. Finally, in the context of the ARCHES project which aims to be inclusive through its use of participatory methods we would argue that designing technologies so that their use is not directly controlled by the user, works against one of the underlying principles of participatory research: 'Nothing About Us, Without Us' (Charlton, 1998).

The case for a focus on diversity and difference

With the removal of the tailor-ability principle, the remaining four principles suggest that the technology developers in our review conceptualised their users in a number of ways:

- Usability design principles- user is anyone (with or without a disability);
- Accessibility design principle- user is anyone who is disabled;
- Agency- user is anyone who is disempowered or excluded;
- Learning support – user is anyone with a learning difficulty.

Furthermore, if the seven papers that only referred to the tailor-ability principle are removed from the corpus (papers 1, 2, 4, 9, 22, 24, 43); analysis reveals that 25 of the remaining 38 papers referred to two or more design principles (65%) and 13 referred to three or more principles (34%) suggesting a tendency for developers to adopt a mixed design strategy. (See Table 10).

Number of principles	Papers	Totals
All four principles	17, 40, 41	3
Three principles	5, 13, 18, 19, 20, 27, 31, 32, 38, 45	10
Two principles	3, 7, 8, 11, 14, 16, 21, 26, 28, 35, 36, 42	12
One principle	6, 10, 12, 15, 23, 30, 29, 30, 33, 34, 37, 39, 44	13

Table 10: Number of principles referenced by a paper

There could be two reasons for the developers to conceptualise their users in a range of ways and to adopt such a mixed strategy. Firstly, in recognition that their users are diverse. For example, in addition to including users with learning difficulties some studies included learning difficulties that we have chosen not to particularly focus on in the Arches project such as Autism or ADHD as well as participants with other non-learning related differences such as motor impairment, dementia or schizophrenia. Secondly, in recognition that people with learning difficulties have a range of needs. For example, six studies included people with learning difficulties who also had a sensory impairment [17, 20, 34, 38, 40, 41].

Adopting a mixed design strategy, that addresses a diversity of needs has some resonance with the Universal Design approach to education. Broadly speaking, universal design in educational contexts is an approach characterised by anticipating the needs of a diverse group of learners (Meyer & Rose 2000) in which instructors mix their strategies to ensure that the overall mix is inclusive for everyone (Burgstahler, 2010). Many researchers in the field of learning difficulties and technologies advocate the principles of Universal Design. For example, Chadwick *et al.* (2013, p.388) argue:

> *Universal design is critical in allowing people with ID to gain substantial benefits associated with being online. There are a number of principles associated with Universal design and these all affect user interface with the webpage. For example, websites should be flexible, simple and intuitive, contain perceptible information, include tolerance for error and require low physical effort*

We would argue however, that the design framework suggested by our review is distinctly different to universal design in one key regard- it does not ignore difference. If designers of technologies for people with learning difficulties followed the advice from Chadwick et al. (2013) they would employ the usability principle as identified in this review (simple and intuitive, tolerance for error, low physical effort) and the accessibility principle (perceptible information) as identified in this review. They would not however employ the agency or learning support principles; suggesting that their needs as a disabled person might be met, but at the expense of their needs as a person with learning difficulties, or their needs as someone who has little control over the decisions made about their lives. Designing for diversity is important, but not at the expense of designing for specific needs, needs related to specific differences or difficulties- in this case learning difficulties. However, if a technology developer just addressed the learning support principles that we have identified in our review, there is a chance that a person with a learning difficulty would not benefit, as they might not be able to access or use the technology in order to be supported in their learning.

A case for a focus on digital inclusion

The four design principles that we have chosen to focus on in our proposal for a design framework reflect four concepts that dominate digital inclusion discourses: use, access, empowerment and participation (See Table 11).

Use

In the digital inclusion literature there is a growing recognition that the quality of technology usage needs to be addressed. Selwyn and Facer (2007) suggest that quality of use can vary considerably depending on issues such as technology platform or level of connectivity (e.g. broadband). Other ways of conceptualising quality of technology use 'meaningful use' (Selwyn, 2004, p.349) or 'smart use', where smart use is defined as making use of technologies as and when appropriate (Selwyn and Facer 2007, p.14). Understanding what influences use and therefore digital inclusion, is likely to involve more than understanding barriers to the acquisition of skills or competences. It is likely to involve understanding an array of factors that influence the decisions that learners make about when technology use is appropriate or meaningful in their lives. In the context of this review and the Arches project, we would argue that the Usability design principle, addresses designing for quality use, where quality use is understood as unimpeded use. If designers follow the two usability principles of simplicity and efficiency, users with learning difficulties are offered the path of least resistance towards the learning content and experiences. Their path to learning is not impeded by complex and inefficient user interfaces.

Design Principles	Digital inclusion concept	Exemplification in the context of learning difficulties and the ARCHES project
Designing for usability	USE	Ensuring people with learning difficulties can easily use the technology- use is unimpeded
Designing for accessibility	ACCESS	Ensuring people with learning difficulties can easily access the content or experience being offered by the technology and reducing barriers to meaningful engagement with the content or experience
Designing for agency	EMPOWERMENT	Ensuring people with learning difficulties can exert some control over the content or experience being offered by the technology
Designing for Learning Support	PARTICIPATION	Ensuring people with learning difficulties can learn something from the content or experience being offered by the technology and in doing so, participate in an active way in the arts, rather than being passive consumers of heritage and cultural sites.

Table 11: The role of technology design principles in promoting inclusion of people with learning difficulties in heritage and cultural sites

Access

Digital divide and digital inclusion discourses tend to embed within them an expectation or imperative that digital inclusion happens when all members of society are able to access the affordances offered by technology use (see for example Selwyn & Facer, 2007; Selwyn 2004). Digital inclusion is therefore concerned with addressing inequalities, where those unable to access the affordance of technologies are, disadvantaged, marginalised in society and therefore digitally excluded. In the context of this review and the Arches project, we would argue that the Accessibility design principle addresses the need to enable users with learning difficulties to access the content/learning experience being delivered through the technology which may then facilitate greater access to heritage and cultural sites.

Empowerment

Selwyn and Facer (2007, p.4) stress the importance of enabling individuals to make informed and empowered choices about technology use ‘ whilst ensuring these individuals have ready access to the resources required to enable them to act on these choices.’ The UK government in its consultation paper on Digital Inclusion talked of technology being a ‘vehicle for empowerment, rather than a force for further exclusion’ (HM Government 2008, p.5). In their consultation paper, the government link empowerment to notions of limited opportunity. For example, the consultation document proposes a Digital Inclusion Charter which has enshrined in it the principle of ‘Citizen and community empowerment’, where the most disadvantaged citizens and communities are assisted and motivated to 'achieve increased independence and opportunity through direct access to digital technology and skills' (HM Government, 2008: p61).

In this review, those papers that proposed an ‘Agency’ design principle, did so in recognition that people with learning difficulties have limited opportunities; they are infrequently encouraged to take the initiative particularly if this involves taking some kind of risk (See Seale, 2014) and technology use may have to play therefore in promoting decision-making and initiative-taking. In the context of this review and the Arches project, we would argue that the Accessibility design principle addresses the need to ensure people with learning difficulties can exert some control over the content or experience being offered by the technology

Participation

Eynon (2009, p.278) defines the digital divide as 'the differences between those who have all the necessary digital resources to participate in current society and those who do not'. Resources are understood more broadly than technological equipment. For example, van Dijk (2005) sees successful engagement with ICTs as being contingent on the following aspects of resourcing:

- temporal resources (time to spend on different activities in life);
- material resources above and beyond ICT equipment and services (e.g. income and all kinds of property);
- mental resources (knowledge, general social and technical skills above and beyond specific ICT skills);
- social resources (social network positions and relationships – e.g. in the workplace, home or community);
- cultural resources (cultural assets, such as status and forms of credentials).

Cook and Light (2006, p.52) also challenge us to consider whether a distinction should be made between active and passive participation; where passive participation could be viewed as being on the receiving end of e-services and active participation could be viewed as having an influence on the way technologies are used. Through active participation, citizens would be 'fully included, self-determining participants in a digital society'. Whilst a binary distinction between active and passive might be over-simplistic and open to different perceptions or interpretations, we would argue that it is still important to consider the extent to which a person with a learning difficulty is able to use their technology to participate to the ‘level’ that they desire as opposed to the ‘level’ that is afforded them by others.

In the context of this review and the Arches project we would argue that the ‘Learning Support’ design principle is about increasing the opportunity for people with learning difficulties to increase their mental resources (i.e. their understanding and appreciation of the assets on display within cultural and heritage sites) and in doing so, participate in an active way in the arts, rather than being passive consumers of heritage and cultural sites.

A proposal for a comprehensive design framework

In this discussion section we have scoped the parameters of a design framework that incorporates four key design principles that we have distilled from our literature review (Tables 2,3,4,5, 6). The outcome of this scoping exercise is a proposal for a comprehensive design framework which has the potential to guide design and development practice in the field of learning difficulties, technology and heritage and culture. (See Table 12). We are positioning this framework as comprehensive in that it incorporates all four design principles and offers an approach to addressing a range of users (diversity), a range of needs (difference) and all the components required for full inclusion.

Developers designing technology for people with learning difficulties can design for diversity and difference by designing for the specific needs of people with learning as well as designing for a range of other user needs. They can do this by adopting the 'Learning Support' design principle (Tables 2.1, 2.2 and 2.3) and one or more of the other three design principles (Tables 3, 4, ,5, 6). However, people with learning difficulties will only be afforded optimal inclusion (i.e. full participation) into cultural and heritage sites through their use of technologies if all four design principles are employed. A person with a learning difficulty will not be able learn something from the content or experience being offered by the technology and in doing so, participate in an active way in the arts if they cannot use the technology, access the information on offer through the technology or be an active agent in their own learning.

Diversity & Difference/Digital Inclusion	**USE**	**ACCESS**	**EMPOWERMENT**	**PARTICIPATION**
Designing for anyone –disabled or non-disabled	Usability design principles			
Designing for anyone who is disabled	Usability design principles	Accessibility Design principles		
Designing for anyone who is disempowered or excluded	Usability design principles	Accessibility Design principles	Agency design principles	
Designing for anyone with a learning difficulty	Usability design principles	Accessibility Design principles	Agency design principles	Learning Support Design Principles

Table 12: A comprehensive framework for the design of technologies for people with learning difficulties

SUMMARY AND CONCLUSION

This report has presented the results of an in-depth review of literature focusing on the design and development of technologies for people with learning difficulties in any context (i.e. beyond cultural and heritage sites). The overarching aim of this review has been to use the results of the review to inform the early development work of the technology partners within the Arches project. Our literature search produced 45 papers that met the parameters of our search strategy and these papers were analysed in order to address three key questions:

1. What common design principles can be distilled from the literature?
2. How were the design principles derived or evidenced within the literature?
3. What factors might influence the application of the identified design principles

Through a process of inductive and deductive analysis we identified five core design principles:

1. Learning support
2. Accessibility
3. Usability
4. Tailor-ability
5. Agency.

The review also enabled us to illustrate the nature and utility of these principles by detailing the categories and sub categories that make up these design principles and providing a range of examples to illuminate and add depth to the principles (See Tables 2-6). Our review of how these principles were derived and evidenced suggests that for the most part, the principles were well justified and that the technology developers used three particular sources of evidence to underpin their justification for particular design principles: discussion with parents, teachers and other professionals to identify design priorities; reference to existing principles or guidelines in related fields; and reference other studies and literature.

Our examination of what factors might influence the application of the identified design principles suggest: 1) that the Agency design principle has particular relevance when designing for adults, mobile devices and games 2) the Accessibility and Learning Support design principles are more prevalent when designing for games, mobile devices, and the Internet and 3) the Accessibility principle dominates when designing for independent living (general and way-finding).

Finally, we have scoped the parameters of a design framework that incorporates four key design principles that we have distilled from our literature review. The outcome of this scoping exercise is a proposal for a comprehensive design framework that has the potential to guide design and development practice in the field of learning difficulties, technology and heritage and culture.

Appendix 1: Corpus of 45 articles included in the literature review

Article
1. Carlos Cardonha, Andrea Britto Mattos, and Rodrigo Laiola Guimarães. 2016. A platform to support personalized training of people with disabilities. In *Proceedings of the 13th Web for All Conference* (W4A '16). ACM, New York, NY, USA, Article 33, 4 pages. DOI: http://dx.doi.org/10.1145/2899475.2899493
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4. Aarij Mahmood Hussaan, Karim Sehaba, and Alain Mille. 2011. Helping children with cognitive disabilities through serious games: project CLES. In *The proceedings of the 13th international ACM SIGACCESS conference on Computers and accessibility* (ASSETS '11). ACM, New York, NY, USA, 251-252. DOI=http://dx.doi.org/10.1145/2049536.2049592
5. Stephen Vickers, Howell Istance, and Michael J. Heron. 2013. Accessible gaming for people with physical and cognitive disabilities: a framework for dynamic adaptation. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '13). ACM, New York, NY, USA, 19-24. DOI: http://dx.doi.org/10.1145/2468356.2468361
6. Designing a Kinect2Scratch Game to Help Teachers Train Children with Intellectual Disabilities for Pedestrian Safety Yao-Jen Chang, Ya-Shu Kang, Yao-Sheng Chang, Hung-Huan Liu, Yu-Ling Chiu, Chia Chun Kao October 2016 ASSETS '16: Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility
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8. Jinjuan Feng, Jonathan Lazar, Libby Kumin, and Ant Ozok. 2010. Computer Usage by Children with Down Syndrome: Challenges and Future Research. *ACM Trans. Access. Comput.* 2, 3, Article 13 (March 2010), 44 pages. DOI=http://dx.doi.org/10.1145/1714458.1714460
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11. Franca Garzotto and Manuel Bordogna. 2010. Paper-based multimedia interaction as learning tool for disabled children. In *Proceedings of the 9th International Conference on Interaction Design and Children* (IDC '10). ACM, New York, NY, USA, 79-88. DOI=http://dx.doi.org/10.1145/1810543.1810553

Article
12. An integrated e-learning system for MID and MLD children in Qatar Moutaz S. Saleh; Jihad M. Aljaam; Abdulmotaleb El Saddik 2013 International Conference on Current Trends in Information Technology (CTIT) Year: 2013 Pages: 47 - 53, DOI: 10.1109/CTIT.2013.6749476
13. Mobile learning technology based on iOS devices to support students with special education needs *Computers & Education, Volume 61, February 2013, Pages 77-90* Álvaro Fernández-López, María José Rodríguez-Fórtiz, María Luisa Rodríguez-Almendros, María José Martínez-Segura
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43. Pere Tuset-Peiró. 2011. Modelling individuals with learning disabilities to personalize a pictogram-based instant messaging service. In *Proceedings of the 19th international conference on User modelling, adaption, and personalization* (UMAP'11), Joseph A. Konstan, Ricardo Conejo, José L. Marzo, and Nuria Oliver (Eds.). Springer-Verlag, Berlin, Heidelberg, 454-457.
44. Jinglan Zhang, Peter Purgathofer, Margot Brereton, Geraldine Fitzpatrick, and Florian Güldenpfennig. 2016. Handle the Way: Enhancing Web Accessibility for People with Disability. In *Proceedings of the 2016 ACM Conference Companion Publication on Designing Interactive Systems* (DIS '16 Companion). ACM, New York, NY, USA, 117-120. DOI: http://dx.doi.org/10.1145/2908805.2909403
45. ICT based education for students with special educational needs in Sri Lanka Nadira T. Perera; Induni S. D. Wijerathne; Manori M. Wijesooriya; A. T. Dharmarathne; A. R. Weerasinghe Advances in ICT for Emerging Regions (ICTer), 2012 International Conference on Year: 2012 Pages: 156 - 164, DOI: 10.1109/ICTer.2012.6423026

Appendix 2: Articles categorised by age

Article	Children (0-12) Adolescents (13-19) Adults 20+
[1] Carlos Cardonha, Andrea Britto Mattos, and Rodrigo Laiola Guimarães. 2016.	CHILDREN
[2] Jaime Muñoz Arteaga, Dulce Morales Hndz, Ricardo Mendoza, and Carina s. Gonzalez. 2015.	CHILDREN
[3] Andrea Bonarini, Francesco Clasadonte, Franca Garzotto, and Mirko Gelsomini. 2015	CHILDREN
[4] Aarij Mahmood Hussaan, Karim Sehaba, and Alain Mille. 2011.	CHILDREN
[5] Stephen Vickers, Howell Istance, and Michael J. Heron. 2013.	CHILDREN
[6] Yao-Jen Chang, Ya-Shu Kang, Yao-Sheng Chang, Hung-Huan Liu, Yu-Ling Chiu, Chia Chun Kao October 2016	CHILDREN
[7] Javier Marco, Eva Cerezo, and Sandra Baldassarri. 2013.	CHILDREN
[8] Jinjuan Feng, Jonathan Lazar, Libby Kumin, and Ant Ozok. 2010.	CHILDREN
[9] Franca Garzotto, Mirko Gelsomini, Francesco Clasadonte, Daniele Montesano, and Daniele Occhiuto. 2016.	CHILDREN
[10] Yukako Watanabe, Yoshiko Okada, Hirotaka Osawa, and Midori Sugaya. 2014.	CHILDREN
[11] Franca Garzotto and Manuel Bordogna. 2010.	CHILDREN
[12] Moutaz S. Saleh; Jihad M. Aljaam; Abdulmotaleb El Saddik	CHILDREN
[13] Álvaro Fernández-López, María José Rodríguez-Fórtiz, María Luisa Rodríguez-Almendros, María José Martínez-Segura	CHILDREN
[14] Rogério Colpani; Murillo Rodrigo Petrucelli Homem : 2015	CHILDREN
[15] Chen Li; Horace Ho-Shing Ip 2013	CHILDREN
[16] Annette Haworth & Peter Williams (2012)	ADOLESCENTS
[17] N. Bonet-Codina, A. von Barnekow, and D. Tost. 2015.	ADOLESCENTS
[18] Shubham Toshniwal, Prasenjit Dey, Nitendra Rajput, and Saurabh Srivastava. 2015.	ADOLESCENTS
[19] Tiago Martins; Vítor Carvalho; Filomena Soares; M. Fatima Moreira : 2011	CHILDREN, ADOLECENTS, ADULTS
[20] Tuuli Keskinen, Tomi Heimonen, Markku Turunen, Juha-Pekka Rajaniemi, Sami Kauppinen	ADOLESCENTS AND ADULTS
[21] Mendoza G. Alfredo, J. Alvarez R. Francisco, Mendoza G. Ricardo, Acosta E. Francisco, and Muñoz A. Jaime. 2015.	ADOLESCENTS AND ADULTS
[22] Rosa M. Bottino, Laura Freina, Michela Ott, and Filippo Costa. 2015.	ADULTS
[23] Rodrigo Laiola Guimarães, Andrea Britto Mattos, and Carlos Henrique Cardonha. 2016.	ADULTS
[24] Marina Kultsova, Roman Romanenko, Irina Zhukova, Andrey Usov, Nikita Penskoy, and Tatiana Potapova. 2016	ADULTS
[25] Maria Claudia Buzzi, Marina Buzzi, Erico Perrone, Beatrice Rapisarda, and Caterina Senette. 2016.	ADULTS
[26] Peta Wyeth, Jennifer Summerville, and Barbara Adkins. 2011.	ADULTS
[27] Peta Wyeth, Jennifer Summerville, and Barbara Adkins. 2014.	ADULTS
[28] Yao-Jen Chang, Ya-Shu Kang, Yao-Sheng Chang, and Hung-Huan Liu. 2015.	ADULTS
[29] Jonathan Lazar, Libby Kumin, and Jinjuan Heidi Feng. 2011.	ADULTS

Article	Children (0-12) Adolescents (13-19) Adults 20+
[30] Luke Buschmann, Lourdes Morales, and Sri Kurniawan. 2014.	ADULTS
[31] Lourdes M. Morales-Villaverde1 , Karina Caro2 , Taylor Gotfrid1 , and Sri Kurniawan 2016	ADULTS
[32] Mario Erazo and Gottfried Zimmermann. 2015.	ADULTS
[33] Redhwan Nour. 2015.	ADULTS
[34] Elmar Krainz, Viktoria Lind, Werner Moser, and Markus Dornhofer. 2016.	ADULTS
[35] Yao-Jen Chang and Tsen-Yung Wang. 2010.	ADULTS
[36] Libby Kumin, Jonathan Lazar, Jinjuan Heidi Feng, Brian Wentz, and Nnanna Ekedebe. 2012.	ADULTS
[37] Markus Funk, Sven Mayer, and Albrecht Schmidt. 2015.	ADULTS
[38] C. Sik Lanyi; D. J. Brown; P. Standen; J. Lewis; V. Butkute; D. Drozdik 2011	ADULTS
[39] Cátia Afonseca; Sergi Bermúdez i Badia 2013	ADULTS
[40] David J. Brown, David McHugh, Penny Standen, Lindsay Evett, Nick Shopland, Steven Battersby	ADULTS
[41] Sik Lanyi, C. , Brown, D.J., Standen, P., Lewis, J. ,Butkute, V. 2010	ADULTS
[42] Elena de la Guía, María Lozano, and Victor R. Penichet. 2013.	UNSPECIFIED
[43] Pere Tuset-Peiró. 2011.	UNSPECIFIED
[44] Jinglan Zhang, Peter Purgathofer, Margot Brereton, Geraldine Fitzpatrick, and Florian Güldenpfennig. 2016	UNSPECIFIED
[45] Nadira T. Perera; Induni S. D. Wijerathne; Manori M. Wijesooriya; A. T. Dharmarathne; A. R. Weerasinghe	UNSPECIFIED

Appendix 3: Articles categorised by technology

Article	**Primary Technology** **Other technology**
[1] Carlos Cardonha, Andrea Britto Mattos, and Rodrigo Laiola Guimarães. 2016.	INTERNET WEB PORTAL
[8] Jinjuan Feng, Jonathan Lazar, Libby Kumin, and Ant Ozok. 2010.	INTERNET COMPUTER GAMES
[12] Moutaz S. Saleh; Jihad M. Aljaam; Abdulmotaleb El Saddik	INTERNET-WEB MULTIMEDIA MOBILE DEVICE-PC TABLET
[25] Maria Claudia Buzzi, Marina Buzzi, Erico Perrone, Beatrice Rapisarda, and Caterina Senette. 2016.	INTERNET WEB PLATFORM GAMES
[30] Luke Buschmann, Lourdes Morales, and Sri Kurniawan. 2014.	INTERNET IPAD
[31] Lourdes M. Morales-Villaverde1 , Karina Caro2 , Taylor Gotfrid1 , and Sri Kurniawan 2016	INTERNET IPAD
[32] Mario Erazo and Gottfried Zimmermann. 2015.	INTERNET-WEB
[33] Redhwan Nour. 2015.	INTERNET WEB WIKIPEDIA IMDB GOOGLE GLASS INPUT DEVICE/VOICE RECOGNITION
[44] Jinglan Zhang, Peter Purgathofer, Margot Brereton, Geraldine Fitzpatrick, and Florian Güldenpfennig. 2016	INTERNET-WEB MOBILE DEVICES NEAR FIELD COMMUNICATION TOKENS
[2] Jaime Muñoz Arteaga, Dulce Morales Hndz, Ricardo Mendoza, and Carina s. Gonzalez. 2015.	MOBILE DEVICE
[13] Álvaro Fernández-López, María José Rodríguez-Fórtiz, María Luisa Rodríguez-Almendros, María José Martínez-Segura	MOBILE DEVICE- IPAD AND IPOD TOUCH DEVICES
[16] Annette Haworth & Peter Williams (2012)	MOBILE DEVICE-SMART PHONE OR APPLE IPAD QR CODES
[18] Shubham Toshniwal, Prasenjit Dey, Nitendra Rajput, and Saurabh Srivastava. 2015.	MOBILE DEVICE MOOC MULTIMEDIA
[21] Mendoza G. Alfredo, J. Alvarez R. Francisco, Mendoza G. Ricardo, Acosta E. Francisco, and Muñoz A. Jaime. 2015.	MOBILE DEVICE TOUCH SCREENS
[22] Rosa M. Bottino, Laura Freina, Michela Ott, and Filippo Costa. 2015.	MOBILE DEVICE
[23] Rodrigo Laiola Guimarães, Andrea Britto Mattos, and Carlos Henrique Cardonha. 2016.	MOBILE DEVICE LEARNING MANAGEMENT SYSTEM
[24] Marina Kultsova, Roman Romanenko, Irina Zhukova, Andrey Usov, Nikita Penskoy, and Tatiana Potapova. 2016	MOBILE DEVICE

Article	**Primary Technology** **Other technology**
[34] Elmar Krainz, Viktoria Lind, Werner Moser, and Markus Dornhofer. 2016.	MOBILE DEVICE
[35] Yao-Jen Chang and Tsen-Yung Wang. 2010.	MOBILE DEVICES BEACONS BLUE-TOOTH TAGS
[36] Libby Kumin, Jonathan Lazar, Jinjuan Heidi Feng, Brian Wentz, and Nnanna Ekedebe. 2012.	MOBILE DEVICE- IPAD
[40] David J. Brown, David McHugh, Penny Standen, Lindsay Evett, Nick Shopland, Steven Battersby	MOBILE DEVICES GPS TECHNOLOGY SERIOUS GAMES
[3] Andrea Bonarini, Francesco Clasadonte, Franca Garzotto, and Mirko Gelsomini. 2015	VIRTUAL REALITY SENSORS ROBOTS GAMES
[9] Franca Garzotto, Mirko Gelsomini, Francesco Clasadonte, Daniele Montesano, and Daniele Occhiuto. 2016.	VIRTUAL REALITY MOBILE DEVICE MULTIMEDIA GOOGLE CARDBOARD
[39] Cátia Afonseca; Sergi Bermúdez i Badia 2013	VIRTUAL REALITY GAMES INTERACTIVE WHITEBOARD
[4] Aarij Mahmood Hussaan, Karim Sehaba, and Alain Mille. 2011.	SERIOUS GAMES
[5] Stephen Vickers, Howell Istance, and Michael J. Heron. 2013.	GAMES ACCESS DEVICE (Eye Gaze and other input devices)
[6] Yao-Jen Chang, Ya-Shu Kang, Yao-Sheng Chang, Hung-Huan Liu, Yu-Ling Chiu, Chia Chun Kao October 2016	GAMES MICROSOFT KINECT
[7] Javier Marco, Eva Cerezo, and Sandra Baldassarri. 2013.	GAMES NIKVision TABLETOP TANGIBLE TOYS
[17] N. Bonet-Codina, A. von Barnekow, and D. Tost. 2015.	SERIOUS GAMES
[19] Tiago Martins; Vítor Carvalho; Filomena Soares; M. Fatima Moreira : 2011	SERIOUS GAMES
[26] Peta Wyeth, Jennifer Summerville, and Barbara Adkins. 2011.	GAMES ACCESS DEVICE
[27] Peta Wyeth, Jennifer Summerville, and Barbara Adkins. 2014.	GAMES ACCESS DEVICE
[38] C. Sik Lanyi; D. J. Brown; P. Standen; J. Lewis; V. Butkute; D. Drozdik 2011	SERIOUS GAMES
[41] Sik Lanyi, C., Brown, D.J., Standen, P., Lewis, J., Butkute, V. 2010	SERIOUS GAMES
[42] Elena de la Guía, María Lozano, and Victor R. Penichet. 2013.	GAMES MOBILE DEVICE TANGIBLE USER INTERFACES- RFID TAGS
[45] Nadira T. Perera; Induni S. D. Wijerathne; Manori M. Wijesooriya; A. T. Dharmarathne; A. R. Weerasinghe	GAMES

Article	Primary Technology Other technology
[14] Rogério Colpani; Murillo Rodrigo Petrucelli Homem : 2015	AUGMENTED REALITY GAMES
[37] Markus Funk, Sven Mayer, and Albrecht Schmidt. 2015.	AUGMENTED REALITY MICROSOFT KINECT VIDEO CAMERA PROJECTOR
[15] Chen Li; Horace Ho-Shing Ip 2013	SOFTWARE MICROSOFT KINECT SENSORS
[20] Tuuli Keskinen, Tomi Heimonen, Markku Turunen, Juha-Pekka Rajaniemi, Sami Kauppinen	SOFTWARE PICTURE-BASED INSTANT MESSAGING ACCESS DEVICES- TOUCH SCREEN, SPEECH SYNTHESIS
[29] Jonathan Lazar, Libby Kumin, and Jinjuan Heidi Feng. 2011.	SOFTWARE-OFFICE COMPUTERS
[43] Pere Tuset-Peiró. 2011.	INSTANT MESSAGING SYSTEM PICTOGRAPHIC COMMUNICATION SYSTEM
[10] Yukako Watanabe, Yoshiko Okada, Hirotaka Osawa, and Midori Sugaya. 2014.	DIGITAL DOLL-HOUSE DIGITAL SENSORS COMPUTER GRAPHICS
[11] Franca Garzotto and Manuel Bordogna. 2010.	TANGIBLE USER INTERFACE MULTIMEDIA RFID TECHNOLOGY
[28] Yao-Jen Chang, Ya-Shu Kang, Yao-Sheng Chang, and Hung-Huan Liu. 2015.	PERSONAL COMPUTER WEB CAMERA AR TAGS

Appendix 4: Articles Categorised by context or purpose

Article	Context
[1] Carlos Cardonha, Andrea Britto Mattos, and Rodrigo Laiola Guimarães. 2016.	EDUCATIONAL- BASIC SKILLS
[2] Jaime Muñoz Arteaga, Dulce Morales Hndz, Ricardo Mendoza, and Carina s. Gonzalez. 2015.	EDUCATIONAL- BASIC SKILLS
[9] Franca Garzotto, Mirko Gelsomini, Francesco Clasadonte, Daniele Montesano, and Daniele Occhiuto. 2016.	EDUCATIONAL- BASIC SKILLS STORY-TELLING
[14] Rogério Colpani; Murillo Rodrigo Petrucelli Homem : 2015	EDUCATION- BASIC SKILLS COGNITIVE SKILLS
[18] Shubham Toshniwal, Prasenjit Dey, Nitendra Rajput, and Saurabh Srivastava. 2015.	EDUCATIONAL- BASIC SKILLS
[23] Rodrigo Laiola Guimarães, Andrea Britto Mattos, and Carlos Henrique Cardonha. 2016.	EDUCATIONAL- BASIC SKILLS
[30] Luke Buschmann, Lourdes Morales, and Sri Kurniawan. 2014.	EDUCATION-BASIC SKILLS TRAINING
[31] Lourdes M. Morales-Villaverde1 , Karina Caro2 , Taylor Gotfrid1 , and Sri Kurniawan 2016	EDUCATION-BASIC SKILLS TRAINING
[41] Sik Lanyi, C., Brown, D.J., Standen, P., Lewis, J., Butkute, V. 2010	EDUCATIONAL-BASIC SKILLS INDEPENDENT LIVING VOCATIONAL
[45] Nadira T. Perera; Induni S. D. Wijerathne; Manori M. Wijesooriya; A. T. Dharmarathne; A. R. Weerasinghe	EDUCATION- BASIC SKILLS
[3] Andrea Bonarini, Francesco Clasadonte, Franca Garzotto, and Mirko Gelsomini. 2015	SKILLS TRAINING- COGNITIVE, MOTOR, SOCIAL
[4] Aarij Mahmood Hussaan, Karim Sehaba, and Alain Mille. 2011.	COGNITIVE SKILLS TRAINING
[12] Moutaz S. Saleh; Jihad M. Aljaam; Abdulmotaleb El Saddik	COGNITIVE SKILLS TRAINING COMMUNICATION SKILLS
[13] Álvaro Fernández-López, María José Rodríguez-Fórtiz, María Luisa Rodríguez-Almendros, María José Martínez-Segura	COGNITIVE SKILLS TRAINING
[19] Tiago Martins; Vítor Carvalho; Filomena Soares; M. Fatima Moreira : 2011	COGNITIVE SKILLS TRAINING
[25] Maria Claudia Buzzi, Marina Buzzi, Erico Perrone, Beatrice Rapisarda, and Caterina Senette. 2016.	COGNITIVE SKILLS TRAINING
[39] Cátia Afonseca; Sergi Bermúdez i Badia 2013	COGNITIVE SKILLS TRAINING
[42] Elena de la Guía, María Lozano, and Victor R. Penichet. 2013.	COGNITIVE SKILLS TRAINING
[20] Tuuli Keskinen, Tomi Heimonen, Markku Turunen, Juha-Pekka Rajaniemi, Sami Kauppinen	COMMUNICATION SKILLS TRAINING
[43] Pere Tuset-Peiró. 2011.	COMMUNICATION SKILLS TRAINING
[11] Franca Garzotto and Manuel Bordogna. 2010.	COMMUNICATION SKILLS COGNITIVE SKILLS TRAINING
[5] Stephen Vickers, Howell Istance, and Michael J. Heron. 2013.	LEISURE
[16] Haworth & Williams (2012)	LEISURE- VISITING A MUSEUM

Article	Context
[26] Peta Wyeth, Jennifer Summerville, and Barbara Adkins. 2011.	LEISURE SOCIAL SKILLS
[27] Peta Wyeth, Jennifer Summerville, and Barbara Adkins. 2014.	LEISURE SOCIAL SKILLS
[6] Yao-Jen Chang, Ya-Shu Kang, Yao-Sheng Chang, Hung-Huan Liu, Yu-Ling Chiu, Chia Chun Kao October 2016	INDEPENDENT LIVING-PEDESTRIAN SAFETY
[32] Mario Erazo and Gottfried Zimmermann. 2015.	INDEPENDENT LIVING- ONLINE BANKING
[22] Rosa M. Bottino, Laura Freina, Michela Ott, and Filippo Costa. 2015.	INDEPENDENT LIVING-WAYFINDING
[24] Marina Kultsova, Roman Romanenko, Irina Zhukova, Andrey Usov, Nikita Penskoy, and Tatiana Potapova. 2016	INDEPENDENT LIVING-WAYFINDING
[35] Yao-Jen Chang and Tsen-Yung Wang. 2010.	INDEPENDENT LIVING-WAYFINDING
[34] Elmar Krainz, Viktoria Lind, Werner Moser, and Markus Dornhofer. 2016.	INDEPENDENT LIVING-WAYFINDING
[40] David J. Brown, David McHugh, Penny Standen, Lindsay Evett, Nick Shopland, Steven Battersby	INDEPENDENT LIVING-WAYFINDING COGNITIVE SKILLS TRAINING
[38] C. Sik Lanyi; D. J. Brown; P. Standen; J. Lewis; V. Butkute; D. Drozdik 2011	INDEPENDENT LIVING
[17] N. Bonet-Codina, A. von Barnekow, and D. Tost. 2015.	VOCATIONAL- CLEANING SOCIAL SKILLS
[28] Yao-Jen Chang, Ya-Shu Kang, Yao-Sheng Chang, and Hung-Huan Liu. 2015.	VOCATIONAL TRAINING: SHORT ORDER FOOD PREPARATION
[29] Jonathan Lazar, Libby Kumin, and Jinjuan Heidi Feng. 2011.	VOCATIONAL- WORK-BASED COMPUTER USE
[36] Libby Kumin, Jonathan Lazar, Jinjuan Heidi Feng, Brian Wentz, and Nnanna Ekedebe. 2012.	VOCATIONAL- WORK BASED USE OF COMPUTERS
[37] Markus Funk, Sven Mayer, and Albrecht Schmidt. 2015.	VOCATIONAL-FACTORY WORK
[7] Javier Marco, Eva Cerezo, and Sandra Baldassarri. 2013.	PLAY
[10] Yukako Watanabe, Yoshiko Okada, Hirotaka Osawa, and Midori Sugaya. 2014.	PLAY THERAPY SOCIAL SKILLS
[8] Jinjuan Feng, Jonathan Lazar, Libby Kumin, and Ant Ozok. 2010.	DIGITAL LITERACY-GENERAL COMPUTER USE
[33] Redhwan Nour. 2015.	DIGITAL LITERACY- INTERNET SEARCHING
[44] Jinglan Zhang, Peter Purgathofer, Margot Brereton, Geraldine Fitzpatrick, and Florian Güldenpfennig. 2016	DIGITAL LITERACY- INTERNET SURFING
[15] Chen Li; Horace Ho-Shing Ip 2013	GESTURE RECOGNITION
[21] Mendoza G. Alfredo, J. Alvarez R. Francisco, Mendoza G. Ricardo, Acosta E. Francisco, and Muñoz A. Jaime. 2015.	UNCLEAR

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Brown, D.J., Standen, P.J., Evett, L, Battersby, S., and Shopland, N. (2010). Designing Serious Games for People with Dual Diagnosis: Learning Disabilities and Sensory Impairments. In *Educational Gaming.* Chapter in Zemliansky, P and Wilcox, D. M., (eds), Educational Gaming, IGI Global.

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Williams, P. (2012), ‘‘Web site usability testing involving people with learning disabilities using only images and audio to access information’’, Journal of Research in Special Educational Needs (in press, Pre-publication early view, doi: 10.1111/j.1471-3802.2012.01235.x)